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ABSTRACT

This paper discusses batch processing; and on-line, time-sharing operations, and their associate input/output equipment. Special emphasis is placed on electronic display equipment. It concludes that future equipment trends will allow the user more and easier access to the machine he uses. (Author)

OPERATION PEP/EXECUTIVE INFORMATION SYSTEMS MTP-78

INPUT/OUTPUT TRENDS

J. Mitchell

June 1968

This paper has been especially adapted for distribution to the California Educational Administrators participating in the "Executive Information Systems" Unit of Instruction as part of the instructional program of OPERATION PEP (Prepare Educational Planners).

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ACKNOWLEDGMENT

This paper was developed from a series of orientation lectures on batch processing and on-line time-sharing operation, and their associated input/output equipment, given by the author to senior United States government personnel as a part of the Executive Orientation Program previously sponsored by The MITRE Corporation jointly with the Electronic Systems Division of the U. S. Air Force Systems Command.

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SECTION I

SCOPE OF PAPER

One current trend in computer input and output equipment aims at putting the user in a close working relationship with the machine, attempting to reduce the need for trained programmers and other technically trained help as intermediaries. In their place is to be substituted time-sharing, on-line modes of operation designed to allow the user direct access to the machine.

I will first discuss the input and output equipment used in the conventional batch-processing application of computers, pointing out the difficulties in using batch processing for solving problems which are ill-defined, and indicating how time-sharing systems and on-line operation may help with such problems.

Then I will describe in some detail the kinds of input and output equipment useful for on-line work, and will show how they can be applied. Most of the detail I present is concerned with electronic displays because these seem to be the most versatile equipment for on-line use.

Finally, I will summarize the merits of the different kinds of displays and give some indication of what I think the future developments will be.

SECTION II

BATCH PROCESSING

Most computing today is done in some form of batch-processing operation. The user must submit his problem through programmers (if he is not himself a competent programmer), coders, key-punch operators, and operators to get his job onto a machine. The jobs of many users are then batched together. For instance, a small computer may simply be used to enter several jobs onto a magnetic tape which then serves as a very fast input for a large computer. This batching makes the use of the big computer efficient in that many jobs can be run in a given time.

The most common input medium in a batch-processing facility is punched cards. The punched card reader shown in Figure 1 is used in the Bedford Computational Facility to feed the STRETCH computer; it will read cards at a rate of up to 1,000 a minute.

Figure 1. Punched Card Reader

Most batch-processing output is provided by a high-speed line printer. The printer in Figure 2 is also in the Bedford Computational Facility. It prints 600 lines a minute of up to 132 characters each. Printers with speeds up to 1100 lines a minute are available commercially today for routine operations.

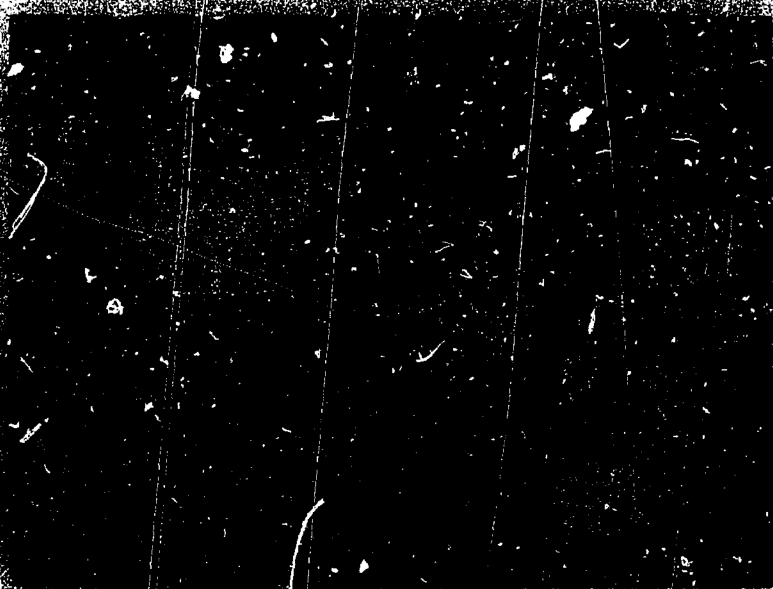


Figure 2: High-Speed Line Printer

While batch processing may be an efficient way to use computer time, it is not necessarily an efficient way to solve non-repetitive problems. With batch processing, the problem necessarily passes through many hands; errors and misunderstandings can easily occur along the way. Errors are often made by the user himself while trying to define his problem. Whatever the cause, errors do occur, and there are frequently many attempts before any given problem is explicitly and properly presented in a computer-under-

standable form so that there can be a solution. Further, with a number of people involved, each attempt to run the program may require several hours for a complete cycle. Often it will be several days before one can get even a relatively simple program in workable condition.

Let me give you an example, a very simple one, of a kind of time loss I am talking about. In Figure 3 are two program statements that a programmer might make. One the computer will accept, the other it will not. The error is simply the omission of a comma between the "0" and the "32" at the end of the line. It may have been omitted by the programmer or by the key

```
WRONG   IDUMMY = IDPU(IXTU(INCONN,0,32), INCO, 032)
RIGHT   IDUMMY = IDPU(IXTU(INCONN,0,32), INCO, 0,32 )
```

Figure 3. Example of Program Instructions

punch operator when she punched the programmer's statement. Given normal human fallibility, such errors are common. The computer will find the error in perhaps one second and return a statement pointing out the error, but in a batch-processing operation three to four hours may elapse between the time the man with the problem submits his punch cards to the computer center and the time he receives back his rejected program. When he receives the rejected program, the initiator must find the error, correct the faulty card and resubmit his punched cards to the computer operator. In three or four hours he may receive back an accepted program, or perhaps he may find that the computer has found a new error that the first error had obscured, and so it goes.

The situation isn't as bad as it might sound. Programmers are not idle during the turnaround time: they generally work on several aspects of a big job at one time. But it is clear that one could make much more effective use of his time and solve his problem sooner if he could obtain 4-second (or even 4-minute) turnaround rather than 4-hour turnaround.

SECTION III

ON-LINE. TIME-SHARING OPERATIONS

Let us consider a different relationship between a user and the computer. The user sits down at the computer console and describes his problem. Perhaps he will have the first pass at a program in a deck of punched cards which he feeds in. Quickly the computer finds errors in the deck--punctuation mistakes, spelling mistakes, incomplete specifications--and through the console brings each to the attention of the user.

The user may look at various registers of the computer in order to increase his understanding of the error, and when he does understand it he can immediately enter corrections through a keyboard.

Once the routine errors have been corrected, the program can be started. It will undoubtedly halt once again, perhaps because of some error in the problem description. Again, the user can look at the computer registers and examine the status of various quantities in his program to find out what happened. In many cases the program can be corrected fairly readily and again restarted; in some cases major rework is required, and the user goes back to the drawing board.

And so the job goes. Each programming or coding error which previously took three or four hours to uncover and perhaps several runs to understand and correct can be discovered in seconds and corrected at once. A program which took days to become operational can be finished in an hour or two. The time needed to correct the mistake illustrated in Figure 3 would only be one or two minutes with this kind of operation, and most of that time would be spent in entering the new statement.

This rapid man-computer interaction I have just described is an example of "on-line" operation. Even more subtle and powerful interactions between user and computer are possible. However, to turn over a large, expensive computer to any one user exclusively for a couple of hours at a time is not practical either. During most of this time the expensive computer would be idle, waiting for him to respond to its last error report. This brings us to the concept of time-sharing.

In the last few years several organizations have been developing the idea of sharing a computer's power among many users, giving each a few seconds or minutes of processing time before going on to the next. This is time sharing. With a time-sharing system, although the user may sit at a console (one of many) for several hours to work out his problem, getting rapid responses to each correction and new attempt he makes, he uses the computer itself for only a few seconds at a time. Many other users are sitting at other consoles and having their problems worked on during the same period. In the background, whenever no console is using the machine, a payroll job can also be done in a more conventional manner. In this way a computer facility can hope to achieve the best of both the batch-processing and the on-line worlds.

Naturally, there are drawbacks. Computer time will not be used as efficiently as in a batch-processing mode, because time is lost as the computer transfers programs back and forth between core and auxiliary memories, and does the bookkeeping necessary to keep track of all the various jobs at all times. And the system won't be quite as good for the user as having the computer all to himself, because his requests for computer action will be delayed by other users' requests and he may have to wait a few seconds longer for responses. Nevertheless, it does seem quite clear that, for any sizable

computer facility which is not committed either to simple repetitive work or to lengthy scientific computations almost all the time, time-sharing systems and on-line operations are very attractive.

On-line operation requires different input/output equipment than batch processing. A man working on-line will not use a punch card reader except for his initial program loading. It is simpler to connect the keyboard directly to the computer than to go through the intermediate card step. And the man will not usually use the volume of output available from a line printer while he is on-line. Intermediate results, as man and computer approach the desired solution, will generally be presented a line or two at a time.

Three kinds of equipment are especially suited for use in on-line systems: keyboard printers, medium-speed printers, and electronic displays.

KEYBOARD PRINTERS

Figure 4 shows a simple keyboard printer. This is a teletype machine. Electric typewriters are equally useful. Keyboard printers will continue in use because they are cheap, versatile, and easy to use. One can buy some teletypes for $400. More rugged versions, and input/output typewriters with larger character sets and better quality output, will cost from $1,500 to $3,000. They are easily connected to a computer, through a phone line if need be. The alphanumeric keyboard provides the ability to enter almost any kind of data or program statements.

The major disadvantage of typewriters and teletypes is the slowness of the output: only 10 to 15 characters per second.

MEDIUM-SPEED PRINTERS

The slowness of the typewriter may be overcome through the use of inexpensive medium-speed printers such as the one illustrated in Figure 5. It will print 200 lines of 72 characters each a minute and costs $10,000 to $15,000. It can provide quantities of output which would take too long to

Figure 4. Keyboard Printer

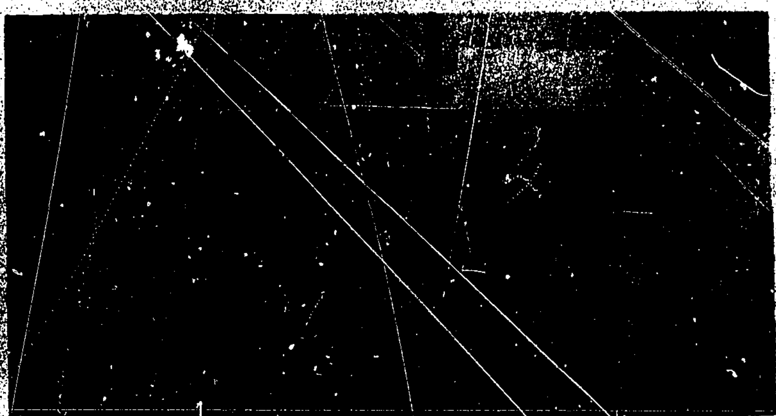


Figure 5. Medium-Speed Printer

produce with a typewriter. The availability of a page of data or instructions in 6 to 10 seconds significantly affects how one uses other input/output equipment. There are two serious limitations: (1) each page of output is quite expensive because special paper must be used; (2) the output quality is not yet as good as desired.

ELECTRONIC DISPLAYS

The third type of equipment, and the kind which is of most interest because of its versatility, is the electronic display. Figure 6 shows a very simplified block diagram which depicts the basic elements of such displays.

(1) A CRT (Cathode Ray Tube) on which the image is presented. Other display surfaces can be used, but the CRT is most common.

(2) A digital data link to an associated computer.

(3) A memory to store data from the computer while it is being displayed.

(4) A display generator to translate the digital data from the memory into analog voltages to deflect and intensify the CRT electron beam.

(5) Input facilities to permit the operator to communicate his wishes to the computer.

I will now talk about the major kinds of electronic displays which are available and discuss their uses and limitations. I will work from television systems through to complex, general-purpose, large-board displays, in color.

Criteria for Display Evaluation

The criteria that I will use in evaluating electronic displays are capacity, flexibility, response, ease of input, and cost.

(1) Capacity. Capacity is measured by the number of easily recognizable characters that can be displayed at any one time.

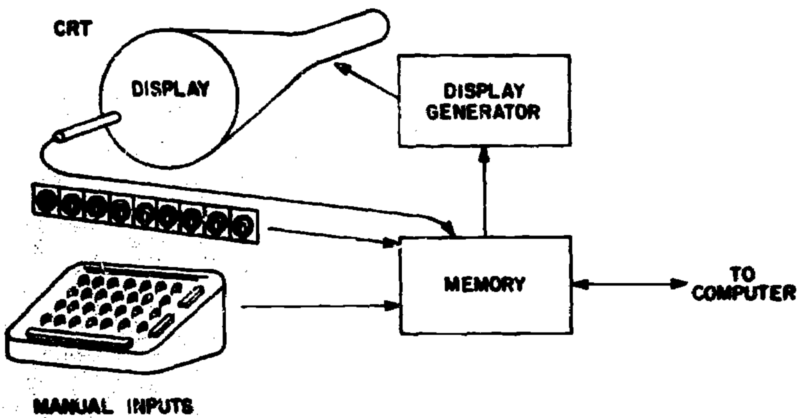


Figure 6. Electronic Display Block Diagram

(2) Flexibility. Flexibility is a measure of the variety of ways in which computer data can be presented, important because the ability of an operator to assimilate the data often depends upon how the data are shown.

(3) Response. Response time is the interval between input from a user and answer from the computer. For most systems I will discuss, the response time is actually limited not by the display response but by computer response and by the bandwidth of the display/computer interface.

(4) Ease of input. The ease with which a human operator can provide inputs affects the ability of the man to work with the computer, using the display as the communication medium.

(5) Cost. Cost has several factors. In general we want as much quality and quantity for our money as possible. However, the user's true needs must be determined. There is no need to buy expensive equipment that a user's operation really doesn't require.

Television

The presence of television sets in our homes and the low cost of receivers have encouraged the use of television for display work. The major advantage of television systems is their ability to transmit pictures immediately, although these pictures are not really computer output displays. The second great advantage is the low cost of expanding the display system. Additional screens can be added for a cost of $400 to $600 each, in more or less unlimited quantity.

When viewed as an on-line computer output, however, television systems have some serious limitations, the first of which is capacity. The dissection of the original scene into a limited number of horizontal lines (less than 500, normally) results in a loss of detail and the breakup of displayed symbols.

Figure 7 shows some characters before television; although the symbols are small they are legible.

However, the breakup of these characters by the horizontal scanning lines of the TV system makes them mostly illegible, as illustrated in Figure 8.

Our investigations of the legibility of televised symbols indicates that one should use 10 to 14 scanning lines for a character in order to be assured of good symbols. The letters ECM in Figure 8 have only about 7 lines and are barely acceptable.

Given these data, it is easy to show that a standard TV system should be used to present no more than about 500 characters. High-resolution TV systems are available which use about 1,000 scanning lines rather than the usual 500. With these systems, displays approaching 1,500 characters can be used, but at about a 30 percent increase in equipment cost and at a considerable increase in bandwidth for picture transmission.

Figure 8. Characters After Being Televised

A second disadvantage of television systems is that it is difficult to provide direct operator input to the computer. Such a communication can, of course, be provided separately--through a standard teletype, for instance--but if one operator is allowed to use the television system for himself, it immediately becomes less useful for others, and the big advantage of television--its cheap, wide distribution--is at least partly lost.

<u>Inquiry Stations</u>

The second class of electronic display equipment that I will talk about is termed an "Inquiry Station." Figure 9 illustrates one of several such devices now on the market.

These displays consist of a small CRT, small memory, and a keyboard. They are often connected to a computer through a telephone line interface. The operator can insert data from his keyboard into the memory and see it displayed before him. He is given facilities for editing the display and for calling for the transmission of all or part of the data in memory to the computer. Similarly, the computer can transmit data to the memory for display, either instead of, or in addition to, the data put up by the operator.

Because these machines cost little--as low as $6,000 in one case--and because they provide much faster computer output than a typewriter as well as much simpler editing controls, they are finding acceptance in the commercial market. The kind of unit shown in Figure 9 has been installed in numbers of stockbrokers' offices for retrieving trading data rapidly. Banks, and at least one railroad system, have installed similar units.

Inquiry stations have the disadvantage of limited display format. They can show only textual displays, although of course the arrangement of the text on the display screen can be tabular. In one or two cases designers have

attempted to provide a sort of graphical capability using horizontal and vertical lines, but the result is still crude. For this reason, data retrieval is currently the prime application.

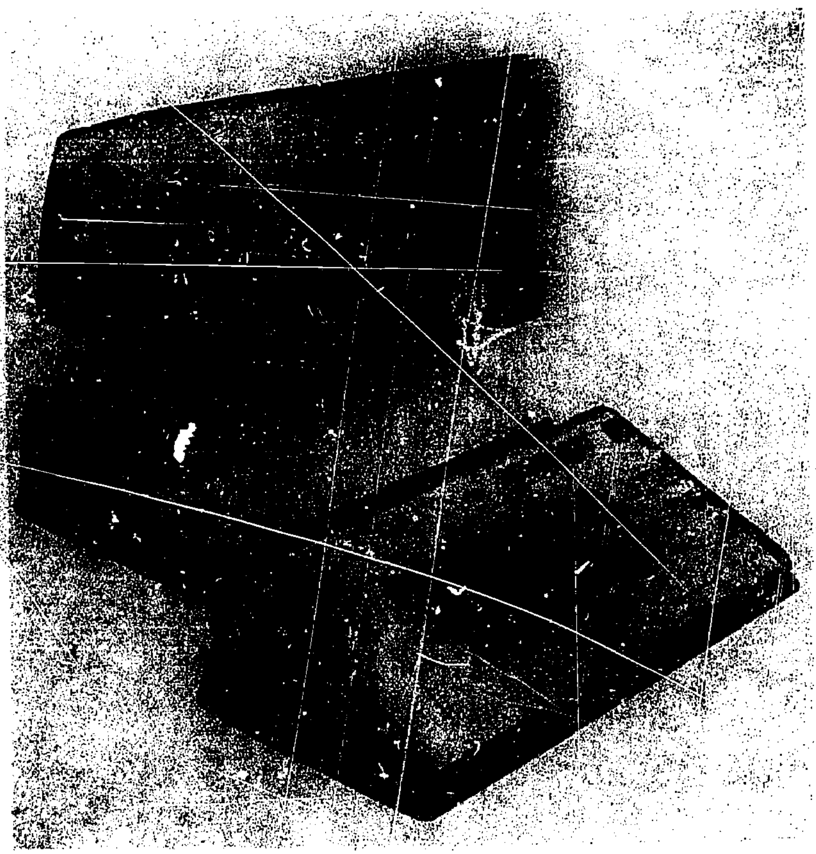
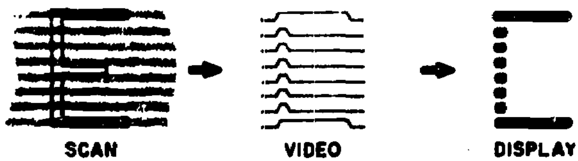


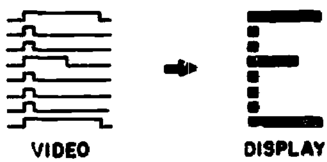
Figure 9. Honeywell Inquiry Station

Figure 10 shows another such display system. This one is interesting because it uses standard television monitors for display screens and therefore it in some ways combines the advantages of both systems--the input and editing controls of the inquiry station, with the possibility of the relatively wide, inexpensive distribution of a television system. Unfortunately, it also combines the expense of both systems; the initial installation cost is about $25,000.

The system illustrated in Figure 10 generates the TV video signal electronically, without the use of a television camera, and for this reason has a higher display capacity than the TV systems I talked about a moment ago. Figure 11 illustrates why this is so.



(a) CAMERA VIDEO GENERATION



(b) VIDEO GENERATION WITH LOGIC

Figure 11. Camera vs Electronic Generation of Video Signal

If a television camera is used to scan an array of characters, printed or otherwise displayed from computer data, some of the horizontal features of the characters between the scanning lines may be lost, as shown in the "E" of Figure 11a. For this reason, in a normal television presentation, up to 14 scanning lines might be needed in a character height. The inquiry station system in Figure 11b generates the TV video electronically. Every horizontal feature deemed essential to good legibility is shown, and only 10 lines per character height are needed. The display capacity of this inquiry station is about 1,100 characters.

Inquiry stations have the advantages of low cost, about \$20,000 plus \$400 for repeated displays or \$1,500 to \$6,000 for new displays. They have limited capacity, 100 to 1,000 characters, and limited flexibility, being restricted primarily to text formats. Only with a typewriter can you get on-line operation for less money. However, a relatively high cost for expansion goes with the low initial cost.

General-Purpose Displays

There is a class of display equipment which I will call "general purpose." Figure 12 shows one such display--there are many different ones on the market. This particular unit was used at the Bedford Computational Facility. These display systems score highly by all the criteria I listed [illegible] shows the variety of input facili- [illegible] ...ail.

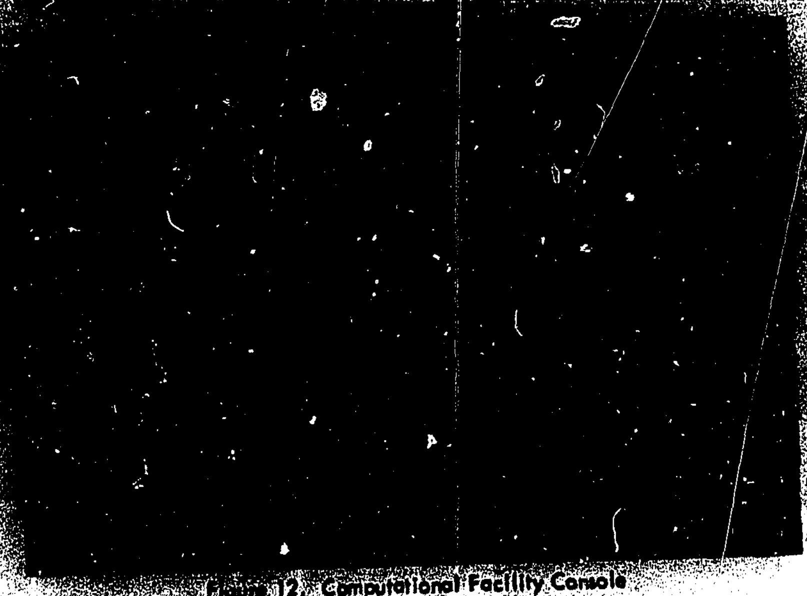


Figure 12. Computational Facility Console

General purpose display systems can generate up to 48 rows of up to about 80 characters per row--an ultimate capacity approaching 4,000 characters. They are quite legible, although there is still room for improvement in this regard.

General purpose displays also permit graphical presentation. In addition, the computer can provide animation--showing, for example, the progress of a satellite around the earth as well as its past position. In a sense, these displays have a pictorial capability through such animation.

General purpose displays have the advantages of flexibility, speed, high capacity, and varied inputs. Their primary limitation is cost, about $60,000 to $150,000 per display. Also, they tend to require complex programming and are too bulky to be readily transportable.

Large-Board Displays

Large-board displays are often chosen for visual access by groups of people simultaneously. Although these are generally film projection devices, I include them in this discussion of electronic displays because the film is generally exposed by a computer-driven electronic display generator. The film may be in a roll or slide form. The display generator may be similar to any of those we have discussed already, although it may be slower, since there is no necessity to regenerate the display rapidly to prevent flicker. The exposure typically takes less than a second. There follows rapid developing and fixing of the film in high-temperature solutions, so that a projectable film is available, either negative or positive, in about 10 seconds. Finally, the exposed and developed film is projected.

Potential users of large boards should recognize that the board capacity is no greater than that of small individual displays, and may be less. This is because the capacity is limited not only by the resolution of the display generator, CRT, and film, but also by the geometry of the display room.

If many people are to see the display, some, at least, are far away, and so the characters must be bigger if they are to be read. Capacity is limited to 1,000 to 2,000 characters at best. A large board to be viewed at 30 feet may have only the capacity of a postcard held at a 30-inch reading distance.

Frequently, large-board displays are proposed with the aim of combining the virtues of the computer-driven display with those of a slide projector. Since rapid processing of color film is not presently possible (nor is a high resolution CRT to expose such film available), color is acheived by exposing three or four images on different parts of a black and white film and project-

screen. The mixing of three primary colors may produce seven different displayed colors. One system, by controlling the relative intensities of the primary colors, even claims more colors than that. However, the resolution of the CRT and the stability and registration between the different images available in display generator, exposure station, and projection station are, in the majority of systems, only good enough to produce fair results. A further difficulty occurs when unintended overlapping is produced. If red and blue and purple convey different meanings, what is the meaning when a blue symbol accidentally overlaps a red one? Some of the lost ground is regained when no attempt is made to superimpose the different images.

Large-board displays are suitable for briefings where it is desired to present large amounts of reference material quickly, or to dramatize ideas. The cost of a computer-driven, large-board display is high: black and white television about $40,000; color television about $100,000; other types from $250,000 up. The response time is in the tens of seconds. Reliability is only fair. With the exception of response time, an ordinary slide projector is better in every way than a computer-driven large-board display; and a good cameraman can provide the user with slides taken from a computer printout or a small display in a few minutes.

Summary of Present Electronic Display Equipment

Figure 13 provides a summary of the manner in which the various electronic displays meet the criteria set down at the beginning of this section. In addition, let me summarize a few other general considerations:

(1) Because of their fast response and live input, television systems provide excellent remote viewing. Because of the very low cost of expansion and relatively low operating costs, television can widely disseminate displayed data.

(2) Because of their low initial cost, inquiry stations have satisfied many fast data retrieval requirements. As the cost comes down further they may replace typewriters for other tasks as well, because the relatively fast output is often useful for such jobs as program debugging.

(3) Because of their tremendous versatility, general-purpose consoles will continue to be used for the many jobs which fully employ joint man-computer teams. Their applications will not be widespread until the price comes down.

(4) Large boards will continue to be used for group viewing, although users should critically evaluate the real need for such expensive equipment.

	LEGIBLE	FLEXIBLE	CAPACITY	RESPONSE	INPUTS	COST
TELEVISION	?	?	MEDIUM	✓	NO	LOW
INQUIRY	✓	?	LOW-MED	✓	TYPE	LOW
G. P.	✓	✓	HIGH	✓	MANY	HIGH
LARGE BOARD	?	?	?	?	NO	WOW

? ADEQUATE IF USED PROPERLY

✓ ACCEPTABLE

Figure 13. Summary of Display Equipment

SECTION IV

FUTURE INPUT/OUTPUT TRENDS

To conclude the discussion of input/output equipment, let me indicate its future development.

We can hope to get better quality at a lower price as electronic displays increase in number. Not too long ago the price of a good general-purpose display came down from about $85,000 to about $60,000, and the latter price includes a small computer. Recently introduced* on the commercial market is a computer display which uses a special kind of CRT —— a direct-viewing storage tube —— to store an image for many minutes. This tube eliminates the requirement for a large memory to store the display data and, additionally, permits repeated display of the data many times a second without the occurrence of flicker. On the basis of this technological advancement, it is not unreasonable to expect that the price of such displays will be reduced to $10,000 within a few years. Increasing use of integrated circuits will significantly reduce the size of the logical part of the displays, making them more easily transportable and more reliable. The CRT itself still seriously limits the size and reliability of electronic displays, but a replacement for the CRT seems a good possibility.

For teaching purposes particularly, displays will become more rugged and reliable. Already one display has been built which will withstand 30G shock, 240 hours in a humidity chamber, and other tough environmental tests.

*The tube was introduced on the commercial market in the Spring of 1968. An experimental version has been in use at MIT for some time.

As we learn more about how to present data to people so that they can take advantage of it most effectively, we will come to use displays better.

On-line systems will include typewriters for a long time because nothing else will be so cheap and easy to use.

Medium-speed printers will probably continue to improve slowly and to reduce in price. They will be used to provide hard copies when needed.

Much other exotic input and output equipment has been talked about in the literature. I am going to close with a very few words about some of the more interesting kinds, just to give you some idea of the prospects for the near future.

Probably the closest to being available is automatic character recognition; by this, I mean the use of special hardware and computer programs to translate printed or written alphanumeric characters into a form usable by the computer. Today, about the only such reasonably reliable equipment on the market is for the recognition of the magnetic characters placed at the bottom of bank checks. This is a specialized and limited character set. Some readers have been built and marketed for recognizing other, larger sets of characters, but in general they will handle only one or two different type fonts and their reliability is only fair. The situation may change radically in five years, with the availability of character readers able to handle, with high accuracy, a variety of different fonts.

The recognition of handwriting or even hand printing is further off but will certainly be attained in a few years. It is quite conceivable that the introduction of reliable character readers will significantly reduce the present reliance on punched cards as the major input medium for computer work.

Automatic speech recognition is also being talked about. However, it seems apparent to me, from an examination of writings on the subject, that speech recognition is a long way in the future.

Speech output from computers, on the other hand, is already available in a limited fashion. A computer can control the assembly of words recorded on magnetic tape. The New York Stock Exchange quotation system operates in this fashion, using some 127 recorded words.

Whatever courses input/output equipment may take in the future, it is clearly the designer's aim to provide computer users with a wider variety of options, greater capacities, finer distinctions, increased speed of interaction, and overall operational capabilities at, I hope, less and less cost.